

SETTING THE MODEL FOR DEVELOPMENT OF A DECISION SUPPORT SYSTEM FOR MACHINE TOOL SELECTION

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Abstract

This paper reports about the initial phase of research concept for the development of decision support system (DSS) for machine tool selection that will enable process planners to get detailed information about the machine during procurement process. In this paper, a machine selection problem in process planning will be presented by setting the decision-making model with defined criteria and alternatives. The main idea is to set general directions for developing a DSS and then conduct a survey among machine manufacturers to collect data, which will be entered in the database. The overall goal of the research is to collect not only the technical and economic data, but also the data concerning energy efficiency of machines. Applying the proposed model in DSS will help the users, i.e. process planners to determine the most energy efficient machine. In that way it will contribute to environmental protection and efficient production environment.

Keywords: machine tool selection, decision support system, energy efficiency criterion

1. INTRODUCTION

Investigations have shown that 20-30% of all process plans are not valid and have to be altered when production starts [1, 2]. Usually, every change in process planning has its consequences and result in lower profit or longer production time. Having in mind that selection of tools and machines is one of the most important activities in process planning, it is very important to have experienced process planners during the procurement process of machines or process of selecting existing machines for producing a new product.

Small and medium enterprises (SME's) are the ones that have the biggest problem with equipment selection due to the budget limitation and the fact that are faced with huge competition and forced to use new equipment that is introduced into the market with technology advances. In that order they can be competitive in time-to-market view and satisfy customer demands. During the procurement process, process planners often don't get detailed information and specification from suppliers (equipment manufacturers) about required machine tool.

Primary, two criteria that have to be fulfilled during machine selection are technical and economic criteria. Except of these two criteria, a very important criterion that is usually not considered is criteria of energy efficiency. Literature shows that the energy consumed in manufacturing, in general, and machining processes, in particular, is significant at the national level and any reduction in energy consumption can have major environmental advantages together with economic benefits [8].

Considering the EU climate and energy package that is a set of binding legislation which aims to ensure the European Union meets its ambitious climate and energy targets for 2020, manufacturers will have to become aware of the energy problem, i.e. the problems of limited availability of energy resources, global warming, etc. The targets, known as the "20-20-20" targets, set three key objectives for 2020: a 20% reduction in EU greenhouse gas emissions from 1990 levels, raising the share of EU energy consumption produced from renewable resources to 20% and a 20% improvement in the EU's energy efficiency [12].

This means that, in order to decrease the ecological impact of a machine, manufacturers will have to start taking energy efficiency features into account during the design cycle of the machine or during redesign of an existing machine. In other words, the machine design process should move to a new paradigm, by going from a purely performance and capacity driven approach to a design approach that uses energy efficiency as a key parameter.

The motivation for this work was to contribute towards an improvement in the process of machine selection, set the new model for further develop of a DSS and give directions for implementation that model in a database that will fulfill the gap of information between machine suppliers and process planners.

2. DESCRIPTION OF PROCESS AND EQUIPMENT SELECTION PROCEDURE

Problem of selecting machine tools and machines in process planning has been analyzed by various researches [1-7], and yet the general procedure or model for selection of the working equipment still has not been adopted in companies.

Kesavan et al. [4] explain that process and equipment selection procedure should be conducted through six formal steps. First step should be development of a general statement of the manufacturing operations to be performed. Second step should establish provisional process to provide each individual feature identified by product designer. This step should insure that no process with a confidence level below acceptable (0,92 is a minimum) is selected. In third step, a list of process alternatives should be developed, particularly for those areas where detailed analysis of the preliminary processing has shown high costs, questionable performance, or places where the confidence level of achieving the requirements is uncertain. After that, in forth step, a careful step-by-step comparison between each phase of the provisional process with each phase of the alternative process should allow process planners to select the best production process, i.e. equipment. In fifth step, when selection is completed, it has to be communicated to the all persons involved in production process to provide co-ordination and communication among all. Finally, in sixth step, detailed process/selection of equipment should be performed.

By Halevi and Weill [3], the most common method of selecting a machine is to consider the size of the workpiece and its accuracy demands and estimate the required parameters, especially power. By this method, a machine is selected before the performance of exact operations, so the machine specifications act as a constraint on the operation selection. Also, as machine has to perform more than one operation, each requiring different accuracy and power, selection of a machine on the basis of the most extreme demands may result in a waste of requires. To avoid this artificial constraint, Halevi proposes separation of the process activities into two phases. First phase, that handles the engineering stage, is limited only by engineering and technological consideration, i.e. includes generation of theoretical process that considers all technical constraints and defines cutting condition, but it does not consider available machines. After that, in second phase the aim is to transform theoretical operations into practical ones, adjusting the process operations to the available facilities. This is a combinatorial problem, which can lead to an untraceable number of alternatives which have to be compared in terms of economic efficiency. Finally, the solution for resolving this problem is given by using dynamic programming.

Researchers have also studied different decision-making problems by using different decision-making methods such as the analytic hierarchy process (AHP), fuzzy multiple-attribute decision-making model, linear and 0-1 integer programming models, genetic algorithms (GA), etc [9]. The problem of machine selection has been generally studied for specific type of environment, like flexible manufacturing machines.

Lin and Yang [13] have used AHP for development of a model for the selection of most suitable machine, from a range of machines available for the manufacture of particular types of part. They used only four criteria for evaluation of machines: machine procedures, lead time, labour cost and operation shift. That three criteria lead to the three alternatives: conventional machines, numerical control (NC) machines and flexible manufacturing cells (FMC). They also used an expert system concept to establish the program and concept expression in the selection of parameters, so the evaluation results can be obtained easily and quickly (Figure 1).

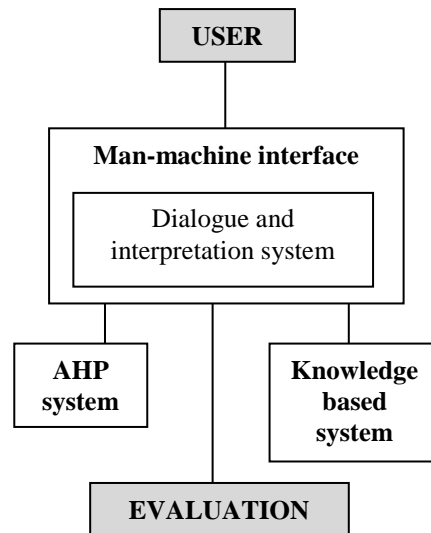


Figure 1 – Expert system framework of the AHP method in evaluating the selection of machines [13]

The work of Lin and Yang has been followed by Arslan et al. [5] by developing a DSS for machine tool selection. They presented selection process in three steps. In the first step, machine specifications (machine name, type, configuration, spindle type and direction, taper number, number of tools, maximum tool diameter, table size, number of axis, machine dimensions, etc.) were compared with the database, and then according to the specifications, database has been modified. For a better selection, force, power and stability calculations were also done so that a match that satisfies operation requirements has been achieved. The multi-criteria weighted average has been used to find machine rankings in the second step, in which several criteria, such as productivity, flexibility, etc., has been used. In the third step, the number of machines that are feasible has been relatively small. The missing additional information has been obtained for these machines and multi-criteria weighted average has been applied to rank the machines again. After the selection of best machine, optional machine features (different spindle speed, different horsepower, additional axis, auto pallet changer, index table, etc.) have been analyzed considering the cost/benefits calculation, which has required an expert decision again.

This research has been upgraded by Çimren et al. [9] with proposed AHP-based decision support methodology. In addition, reliability, precision and cost analyses were used to help the decision-maker to reach an accurate solution. Criteria set, defined by the decision-maker, have been further improved using sensitivity analysis. The main decision criteria that have been used in this research are productivity, flexibility, safety and environment, and adaptability. These four main criteria have corresponding sub-criteria, f.i. productivity depends on speed, horsepower, cutting feed, etc.; flexibility depends on number of tools, number of pallets, rotary table, index table, etc.; safety and environment depends upon standards and regulations regarding safety door, fire extinguisher, etc., while adaptability is the suitability of machine to the existing environment or system.

Giving this review, it is obvious that the energy efficiency criterion has not been considered during machine selection in decision-making methods. As stated in introduction, one of the EU's key objectives until 2020 is a 20% improvement in the energy efficiency. Growing ecological awareness of the energy problem leads to an increasing social pressure to reduce energy consumption in as much domains as possible, and also in the machine building sector.

Moreover, energy prices are increasing as well. The total cost of a machine, which includes next to the purchase cost also the maintenance cost and operation cost, is therefore substantially influenced by the machine's energy usage. Therefore, for better understanding the process of energy use, it is important to give an overview of energy consumption model in machining process.

3. ENERGY CONSUMPTION IN MACHINING PROCESS

Machining is one of the major activities in manufacturing industries and is responsible for a significant portion of the total consumed energy in this sector. Performing machining processes with better energy efficiency will, therefore, significantly reduce the total industrial consumption of energy [10].

The Cooperative Effort in Process Emission (COP2E!) – Initiative divides machine tool states in two categories; basic state and cutting state [14]. The states are based on operational characteristics of the processes. In the ‘basic state’, electrical energy is needed to activate required machine components and ensure the operational readiness of the machine tool. In ‘cutting state’ the energy is demanded at the tip to remove workpiece material as well as for modes of energy loss, e.g. through machine noise, friction, etc.

Balogun et al. [11] have added the third state, called ‘ready state’, that is required to classify the process that takes place after the machine is started (Figure 2). After a detailed research about energy consumption in machining, conducted by [11], authors have developed the mathematical model for calculation of the total energy consumption in machining states:

$$E_t = P_b t_b + (P_b + P_r) t_r + P_{air} t_{air} + (P_b + P_r + P_{cool} + k v_c) t_c, \quad (1)$$

where:

E_t is the direct total energy requirement in [J] or [Ws],

P_b , P_r and P_{cool} are the basic and ready state power (power increment above basic power to bring the machine to the about to cut position) and coolant pumping power requirements respectively in [W],

t_b and t_r are the basic and ready time respectively in [s],

k is the specific cutting energy with units of [kJ/cm³] which is closely related to the workpiece machinability and the specifics of the cutting mechanics;

v_c is the rate of material processing in [cm³/s],

t_c is the cutting time in [s],

P_{air} represents the average power requirements for a non cutting approach and retract moves over the component in [W], and

t_{air} represents the total time duration of non-cutting moves in [s].

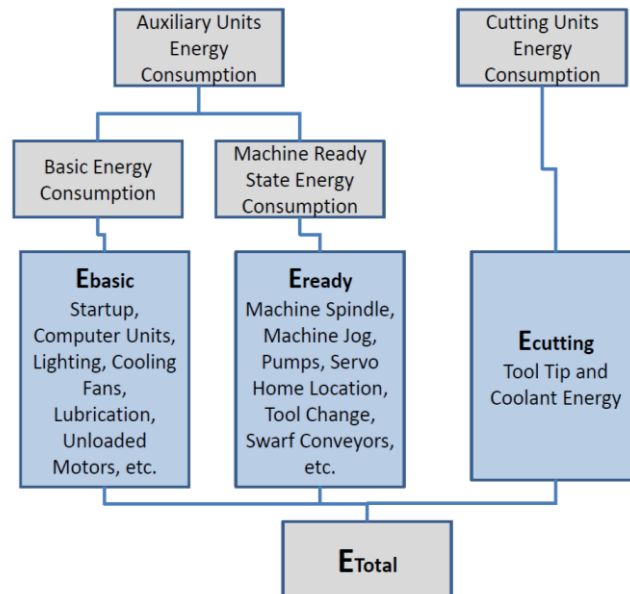


Figure 2 - Machine tool electrical energy consumption estimation model [11]

Figure 2 shows how the electrical energy use is distributed during machining process and indicates the stages where machine can become more energy efficient.

According to ISO 9000, efficiency is the relationship between the result achieved (outputs) and the resources used (inputs). Resources used, i.e. power supplied to the machine tool: electricity, compressed air, cooling by cold water supply, ambient air, optionally at stabilized temperature, etc., can be quantified, while result achieved, i.e. shape, material, features, surface quality, precision, parts produced are case-specific. The efficiency of a process or system can be enhanced by achieving more or getting better results (outputs) with the same or fewer resources (inputs).

To be able to improve energy efficiency of machines, manufacturers will have to understand where energy is being consumed or lost and reduce losses by selecting the optimal adaptations to the design and to the machine parameters. From the user point of view, process planners will have to include energy efficiency criterion as one of the most important criterion.

4. MODEL FOR DEVELOPMENT OF A DSS

Idea of developing a new DSS comes from the need for implementing energy efficient machines in production plants. As stated in introduction, selecting the wrong machine for the work can be critical decision for process planners in case they do not receive all the important information from manufacturers.

Before setting the model, the dataflow for developing a DSS is shown in Figure 3.

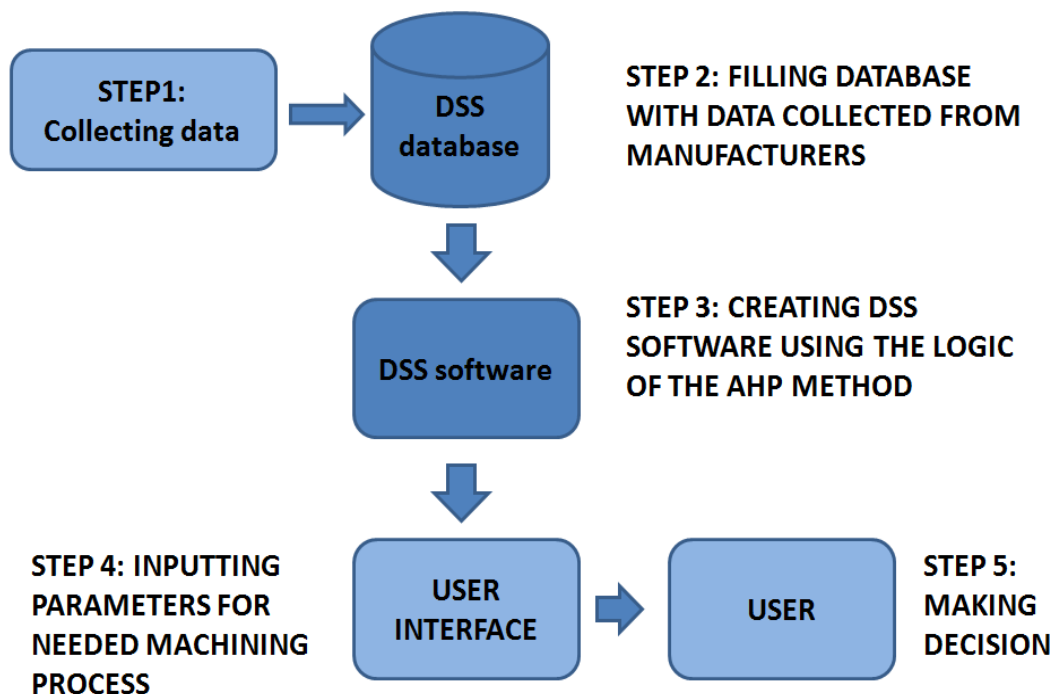


Figure 3 – Dataflow for decision making process

As presented in Figure 3, the dataflow of the decision making process will contain five steps. Method used for development of decision support software will be analytic hierarchy process that will rank machines from the most to least energy efficient after inputting wanted parameters, i.e. type of machining process, batch size, size of the workpiece and machine cost.

Logic for solving the AHP is presented in detail by [15] and it will be very similar to work conducted in [9], but with emphasize on energy efficiency of the machine. A model of the AHP will have three criteria, i.e. technical, economic and energy efficient criterion. Those three criteria will be divided in sub-criteria that lead to the three possible alternatives – conventional machine, NC machines and flexible manufacturing centers (FMC) (Figure 4).

The productivity sub-criterion will provide information about maximum speed, horse power, cutting feed, tool change time and pallet changer. Flexibility implies on number of tools, rotary table, number of pallets, index table, CNC type, U or V axis, head changer, spindle power. The space considers machine dimensions and auxiliary equipment (loading/unloading, material handling, quality). Adaptability criterion consists of CNC

type, number of tools and taper number. Precision implies on axis precision, repeatability, thermal stability, static and dynamic rigidity. Reliability includes bearing failure rate, reliability of drive system, etc., and safety and environment sub-criterion covers information about mist collector, safety door and fire extinguisher.

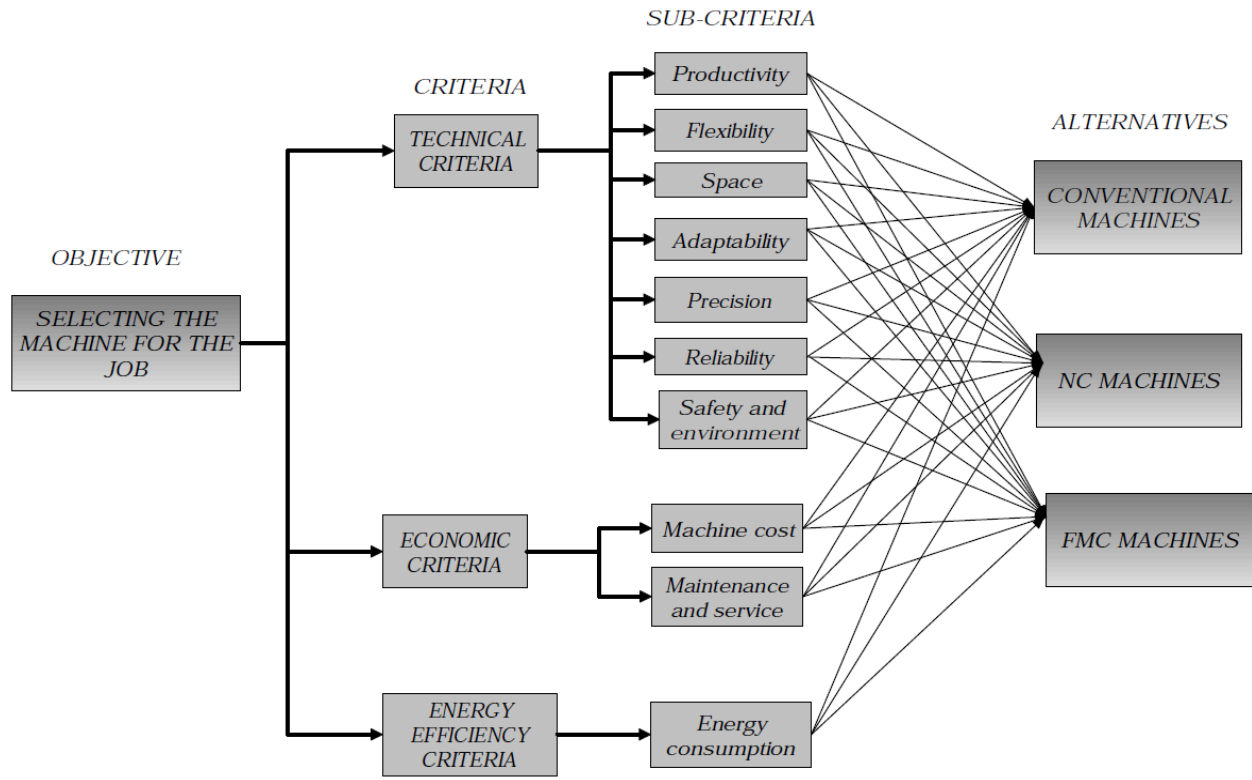


Figure 4 – The hierarchy process for machine selection

As for the sub-criteria of the economic criterion, cost is equal to machine procurement cost, while maintenance and service implies on training costs, repair service, spare parts and regular maintenance costs.

The energy efficiency criterion will include energy consumption in machining process, as explained in chapter 3.

5. CONCLUSION AND FUTURE WORK

The energy efficiency topic is becoming more and more relevant when we talk about selecting machines in process planning. Not only that the legal legislative is going to force companies to use more energy efficient machines, but the companies are daily becoming faced with increasing prices of energy.

This work presents the problem of machine selecting in process planning and a decision-making model for developing of a decision support system. Although there is a great number of catalogs and information spreading around the internet, the idea of developing of a DSS that will chose the machines explicitly by the energy efficient criterion is completely new. To achieve that goal, it is important to get correct and detailed information from the manufacturers about technical, economic and energy specification for the specific machine.

The survey for collecting detailed information and generation of the database is now being created. The decision-making model will continue to evolve based on the experience from process planner and feedback received from manufacturers that will be involved in this project. The model will be transformed into a schema using a PHP internet environment with connection to MySQL database.

The main aim for development of such a DSS is to create a complete database that will be used in eco-friendly process planning to estimate the electricity consumption in production plant. Also, another important goal is to balance the knowledge level between process planners and decrease the level of making bad decisions.

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